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NWFSC

4.1 Impacts of climate change on Snake River salmon

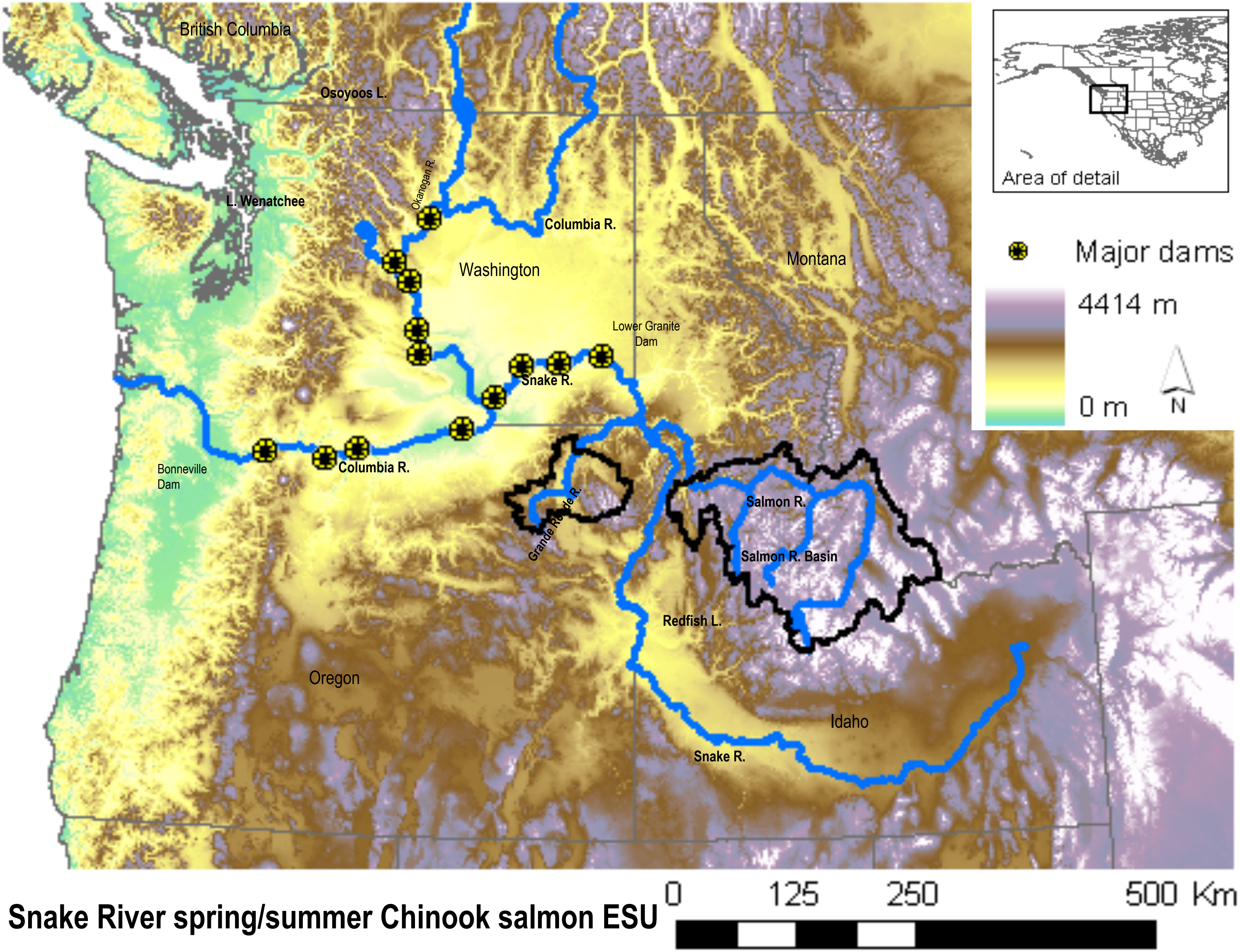
A case study in interconnections and complexity

Lisa Crozier and Rich Zabel

West Coast Protected Fish Species Program Review

Seattle, WA

May 4, 2015



Snake River spring/summer Chinook salmon ESU

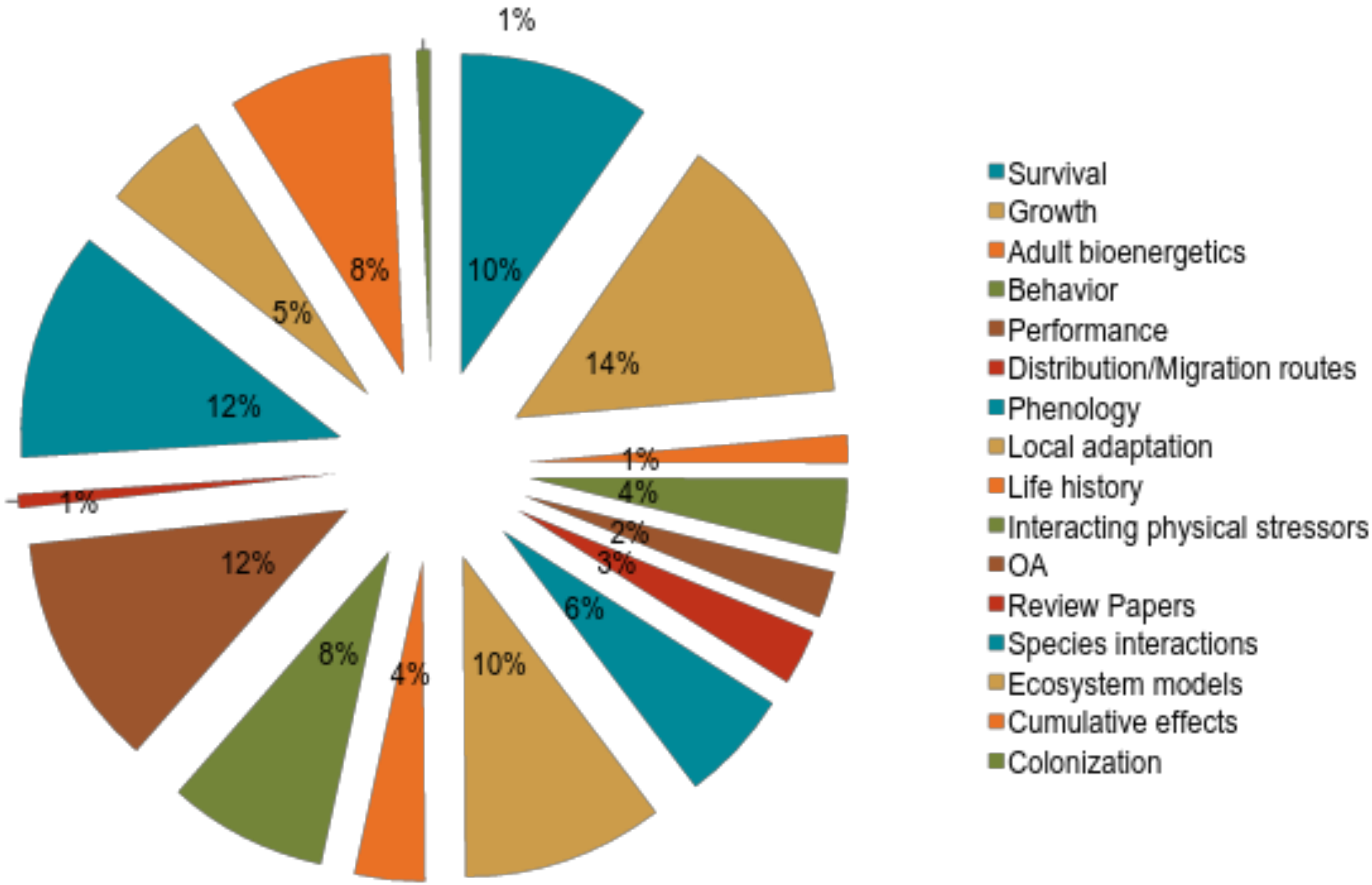
Science to support management needs

- Population-specific viability assessment
- Particular vulnerabilities of populations in relation to climate impacts
- Identify actions that will benefit populations
- Characterize uncertainty in climate change analyses

Case study of salmon in the Columbia River Basin

- Annual literature reviews
- Life-cycle models as conceptual and quantitative tools
- Build knowledge over time to incorporate a wider variety of direct and indirect effects quantitatively

1100 Papers on Climate Change & Impacts on Salmon 2010-2013
All life stages, ecological and evolutionary dynamics affected



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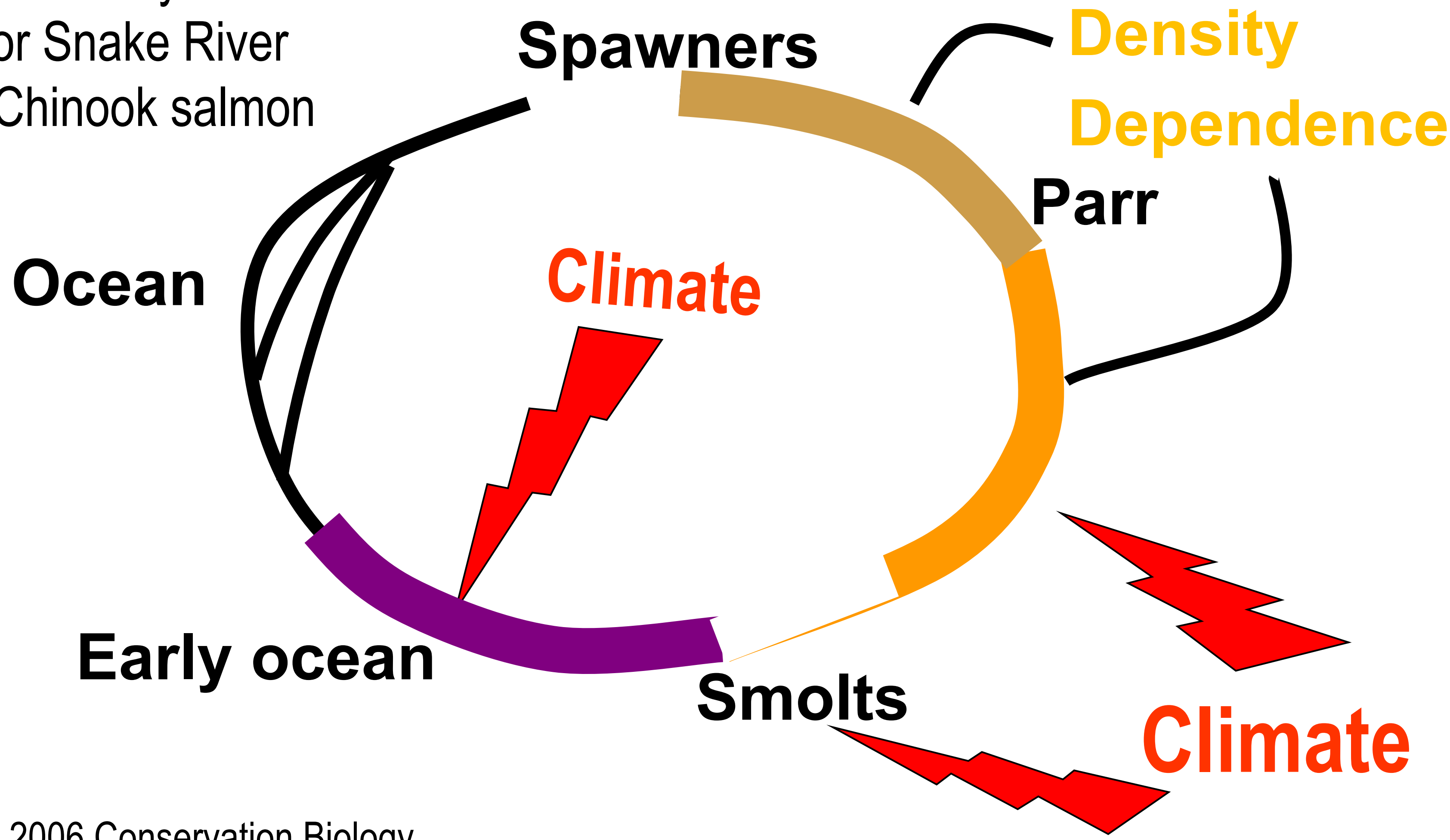
Crozier, L. 2010, 2011, 2012, 2013. <u>Impacts of climate change on Columbia River salmon: annual reviews of the scientific literature.</u>

Population Viability Analysis

Stochastic life-cycle model for Snake River Spr/Su Chinook salmon



Zabel et al 2006 Conservation Biology
Crozier et al 2008 Global Change Biology
Crozier and Zabel 2013 Integrated Ecosystem Assessment

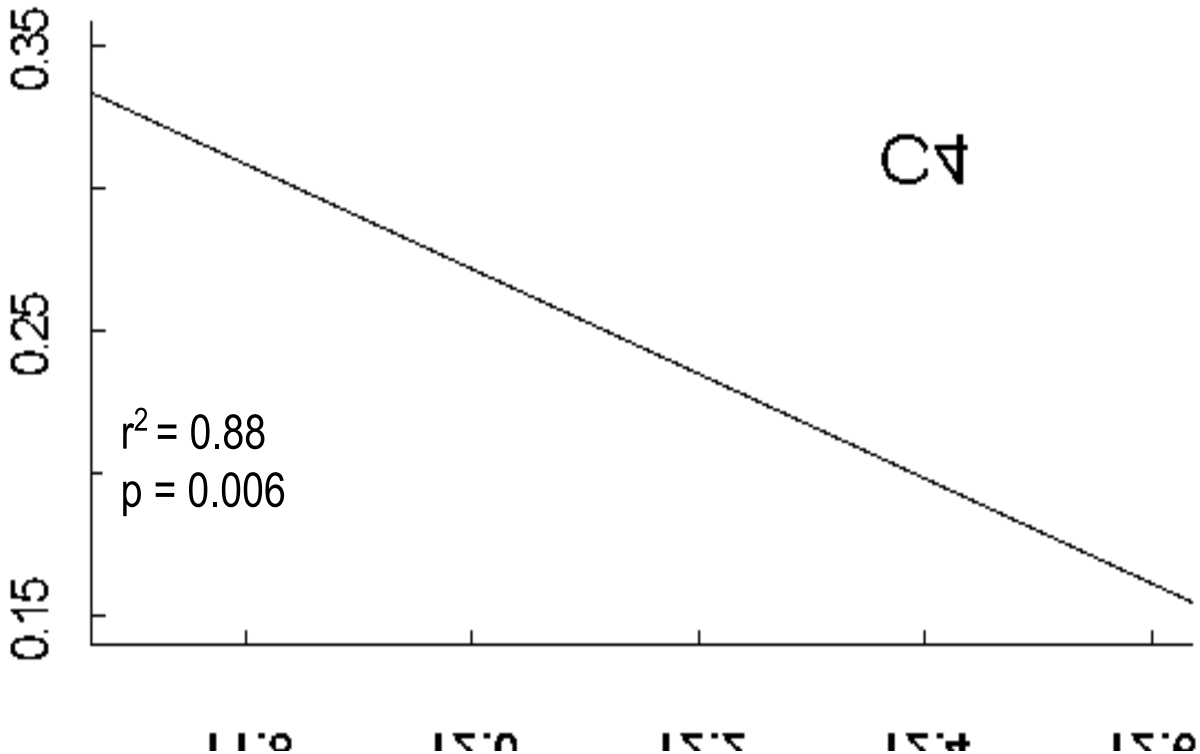
Parameterized for 9 populations

Do temp & flow affect parr-to-smolt survival?

Population-specific sensitivity

Temperature-sensitive populations

Survival



Summer stream temperature (°C)

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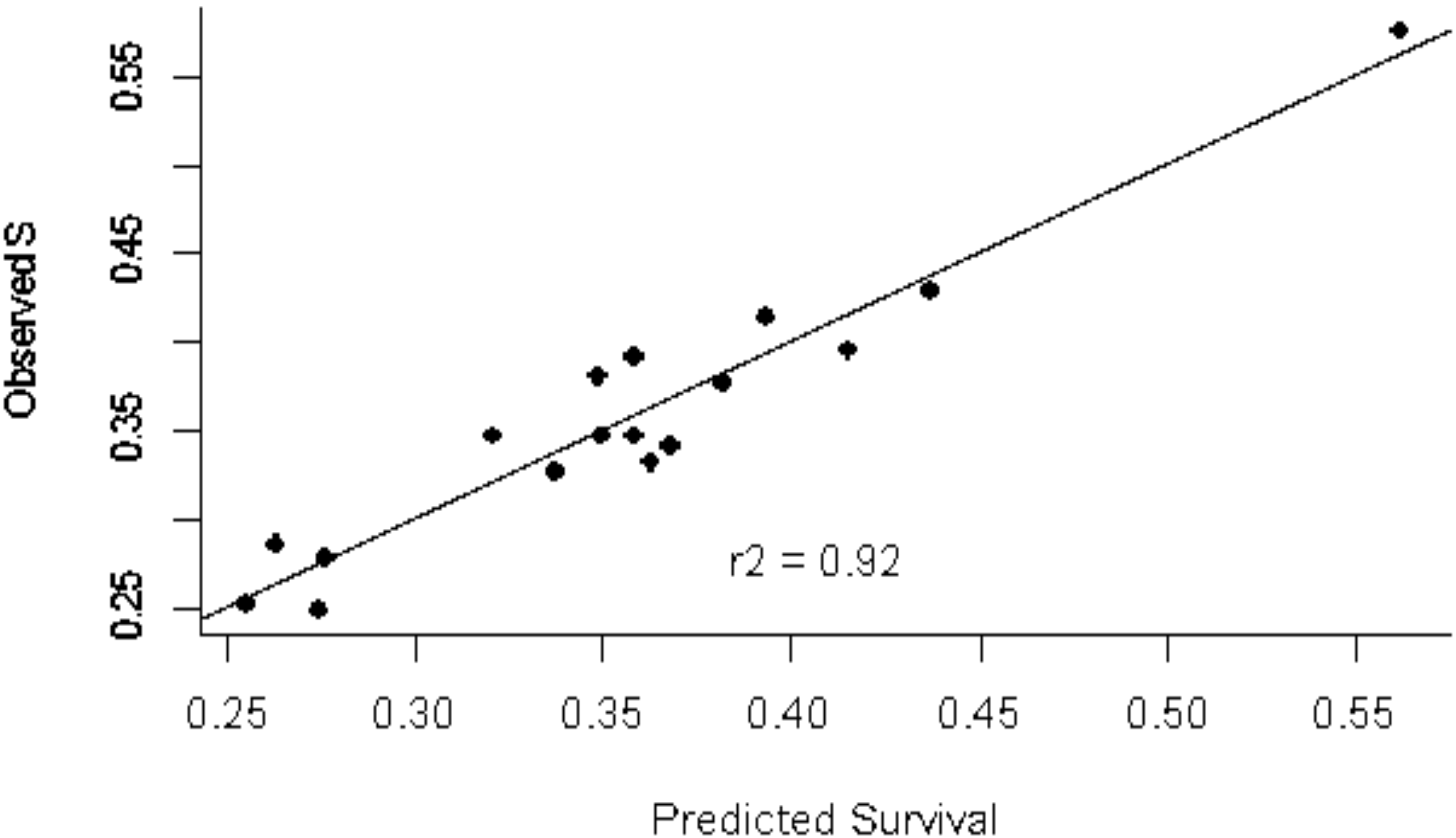
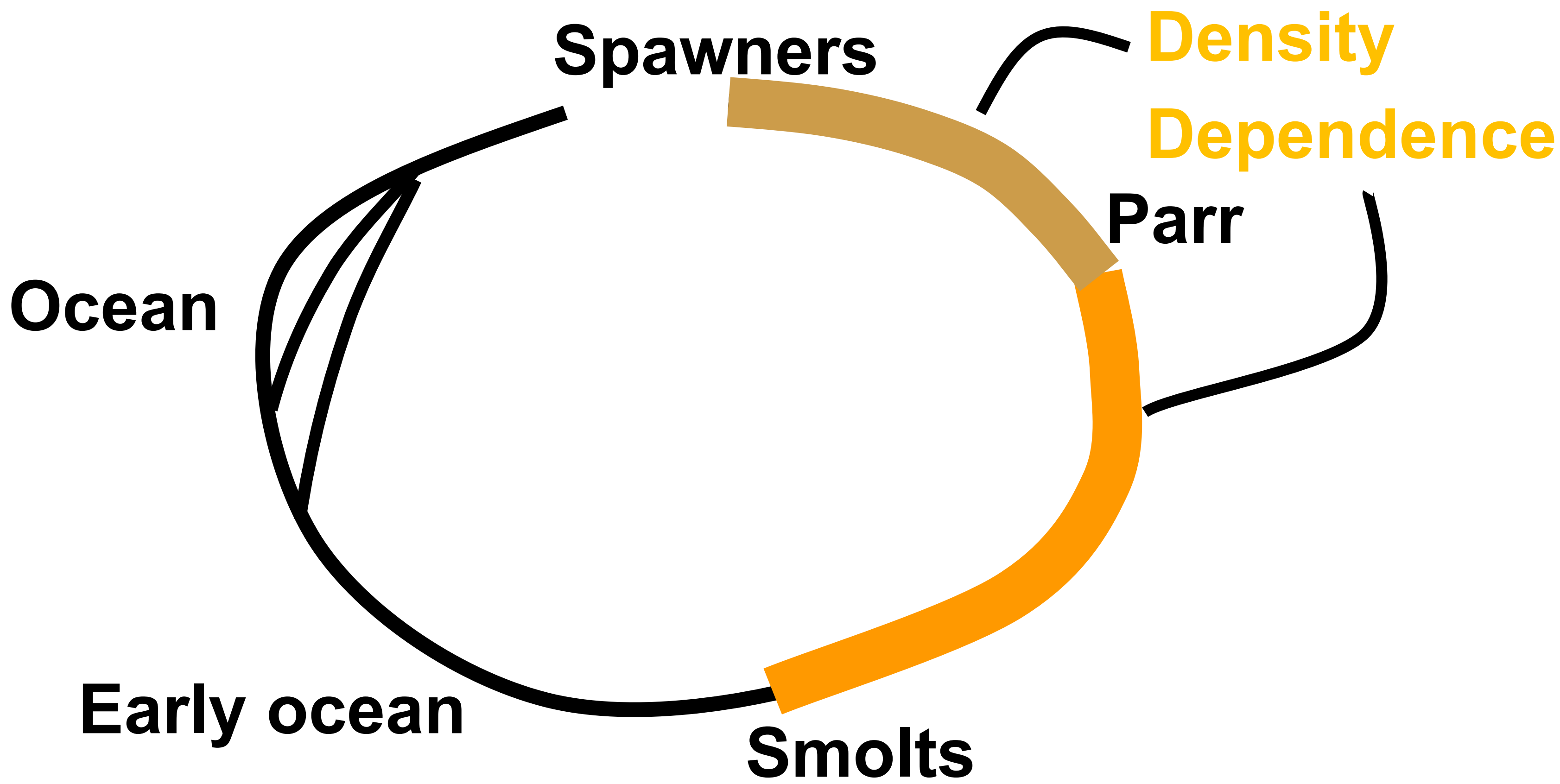
Crozier and Zabel (2006) J. Anim. Ecol.
Crozier et al (2008) Global Change Biology

Parr to smolt survival:
Flow + fish condition (length)



Marsh, Cape Horn, Bear Valley, Elk, Camas

Life-cycle model



Uncertainty and variation in population response in carrying capacity term of Beverton-Holt relationship

FLOW

TEMPERATURE

Posterior distribution

Standardized coefficients

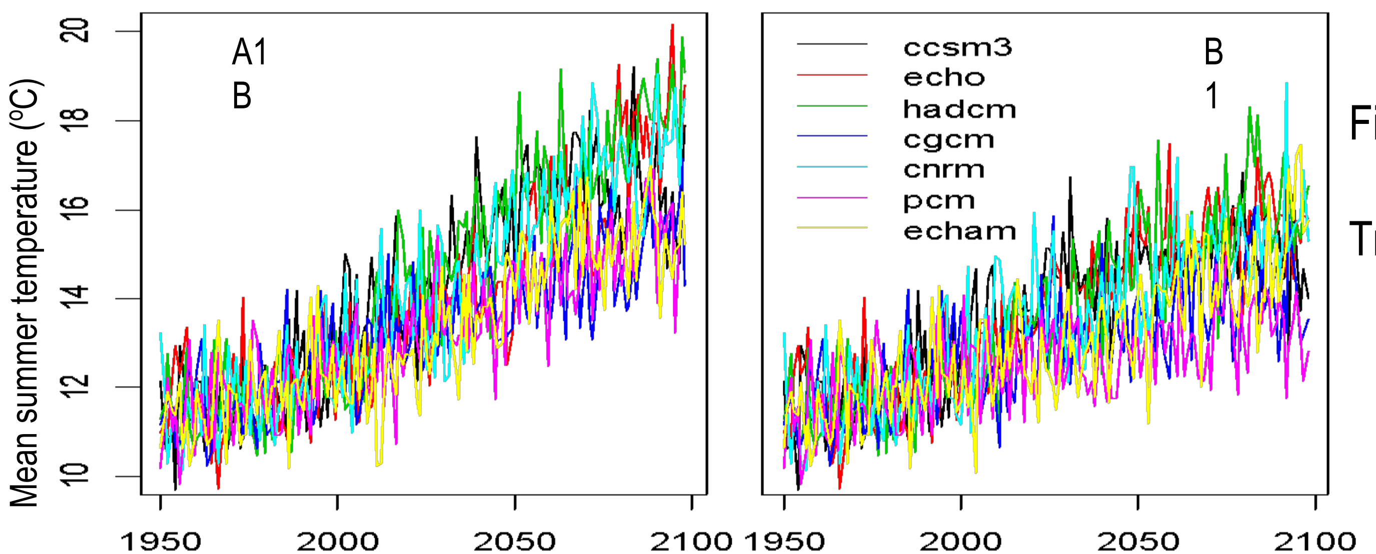
Population

40 Headwater Climate scenarios

Delta Temperature (°C)

2 emissions : A1B & B1
10 GCMs
“hybrid-delta” method
VIC hydrological model

Downscaled by
Climate Impacts Group,
University of Washington



Fixed time periods
vs
Transient scenarios

RESULTS

The effect wner abundance

NEGATIV
E

NEUTRAL

POSITIV
E

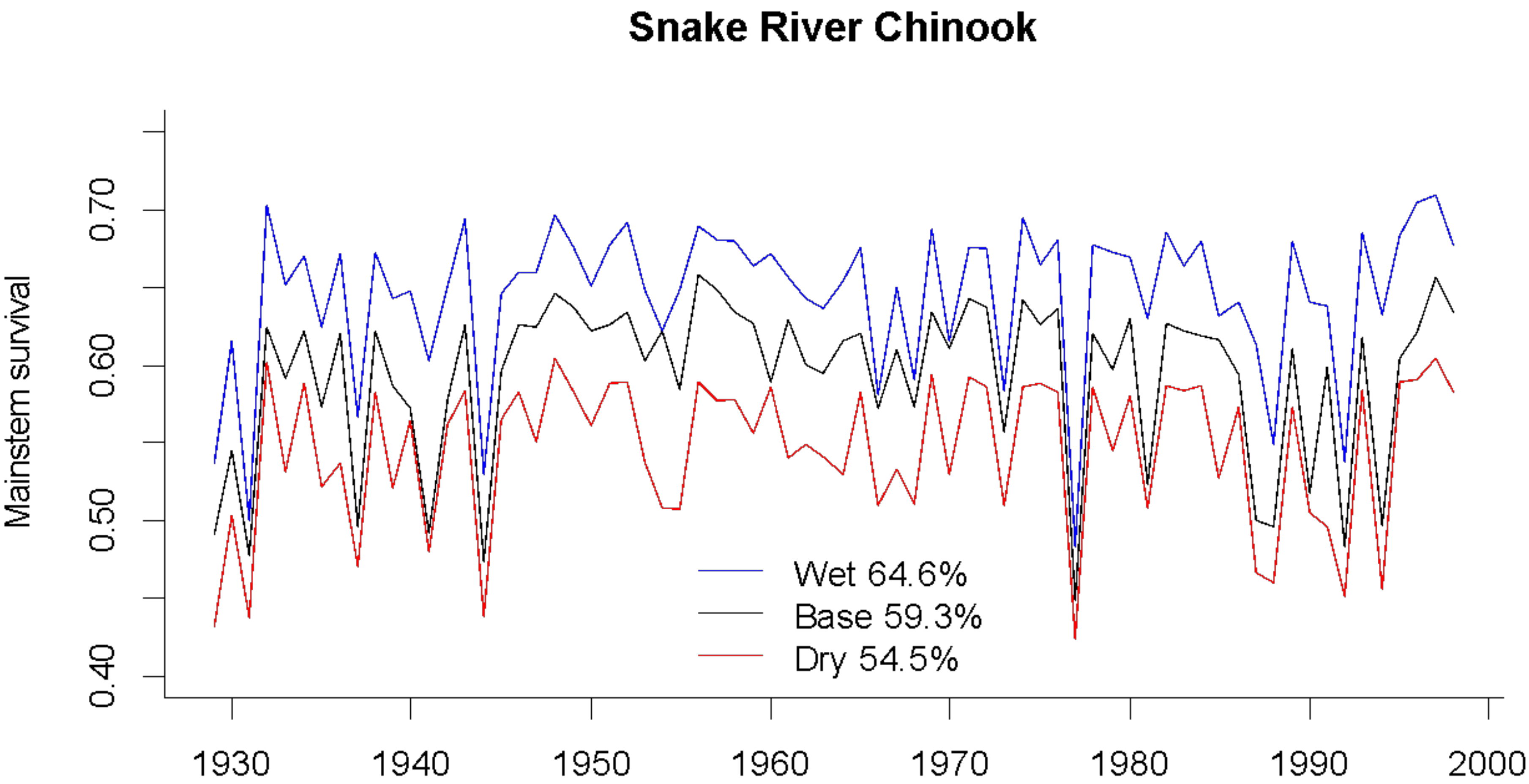
Poor ocean conditions dramatically lower abundanc

Mainstem Columbia & Snake River survival

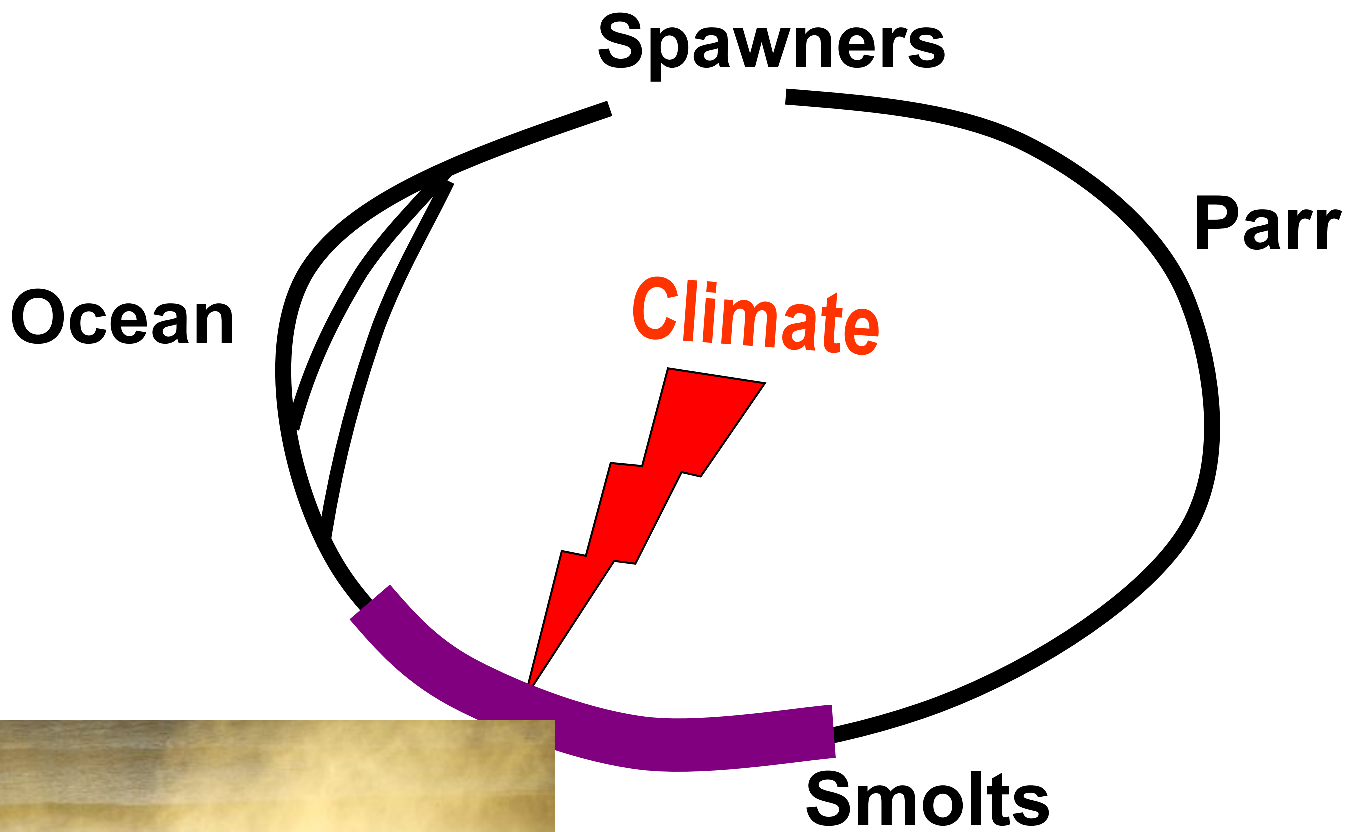
Historical
Wet / more warming -- A1B MIROC 3.2 Global Climate Model
Dry / less warming -- B1 ECHO_G 3.2 Global Climate Model

2040s projections

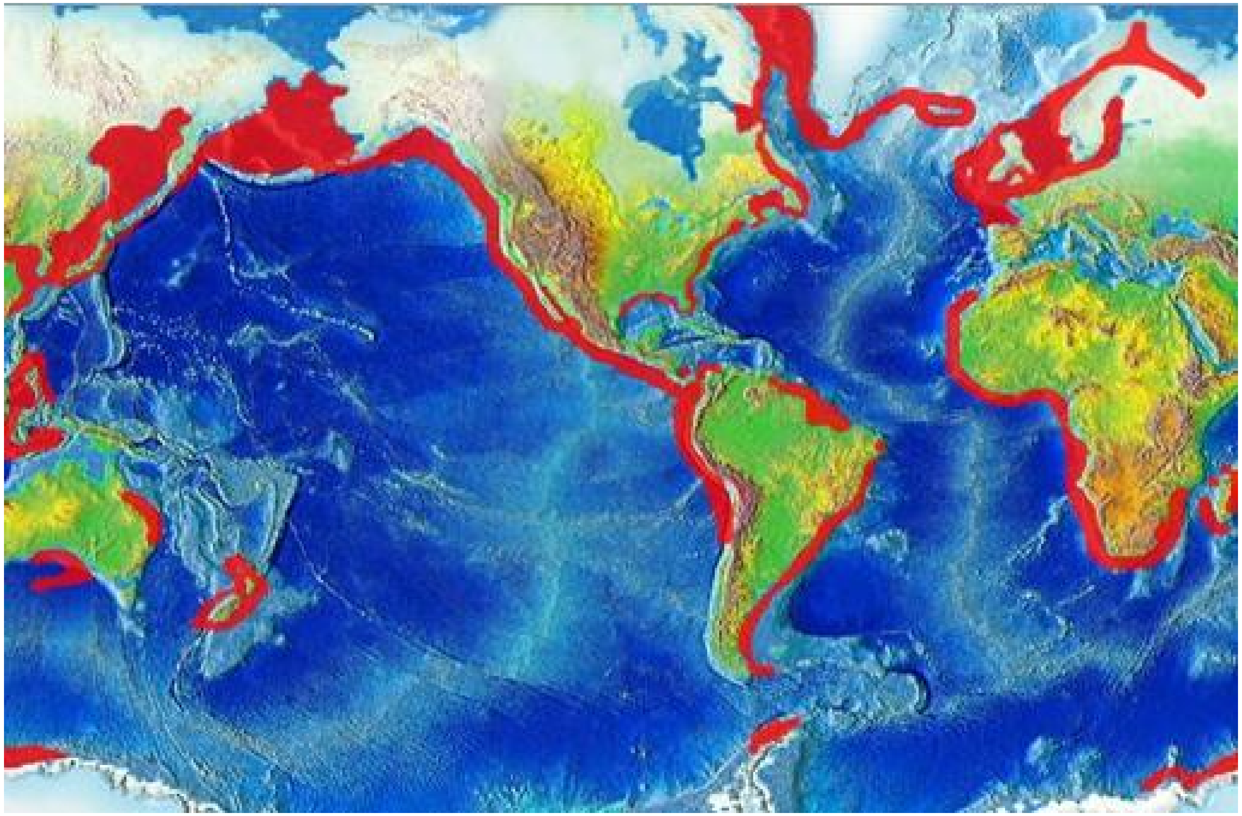
Smolt survival through the hydrosystem



Life-cycle model



Major uncertainties



Upwelling zones drive most productive ocean habitats

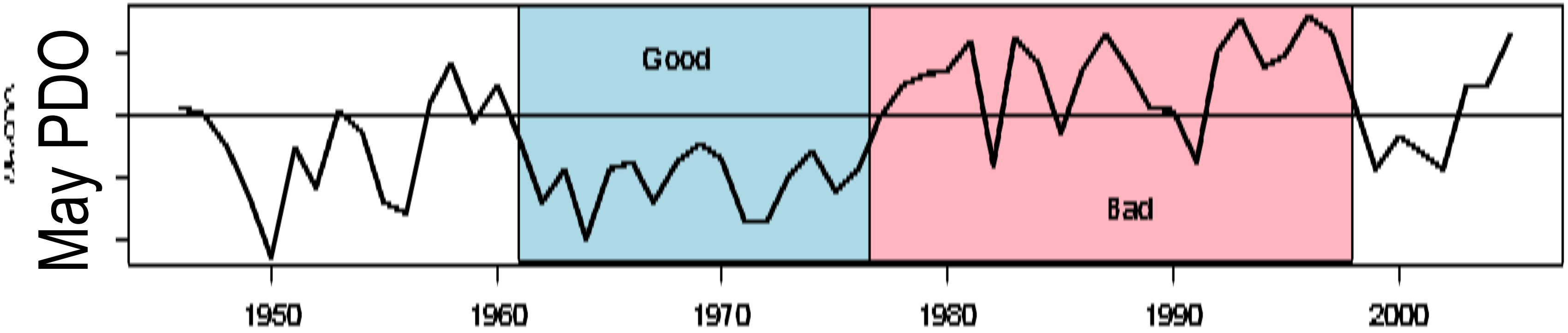
Intensity ↑ or ↓?

Importance of timing shifts?

General ocean changes and impacts on salmon?

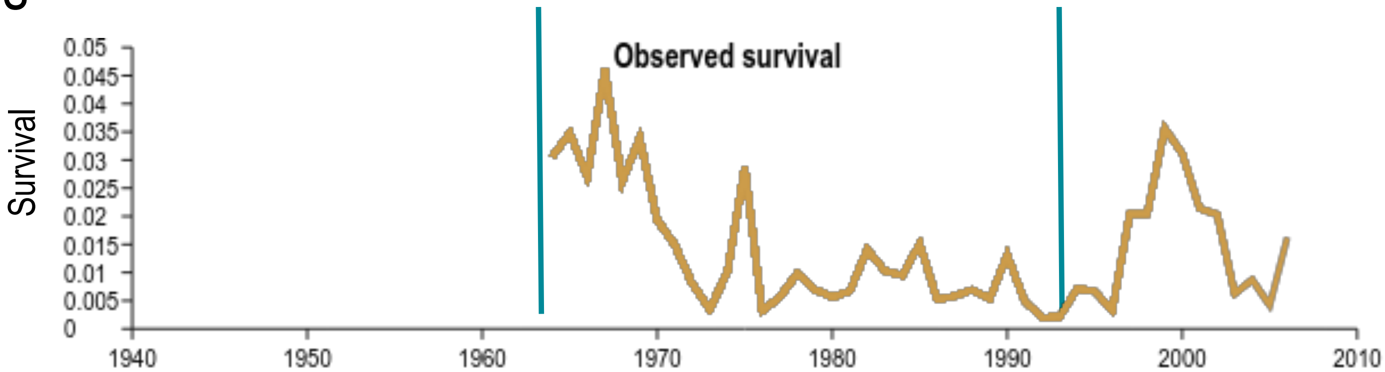
Photo: Wikipedia: upwelling

Ocean regimes



% of time series
in “bad” conditions

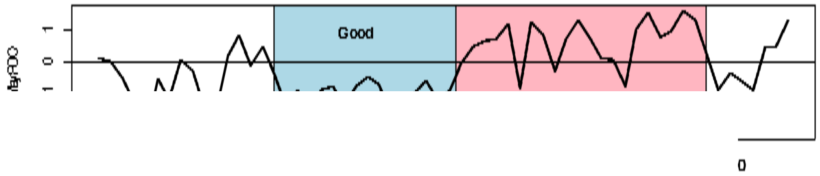
20%
40%
60%
80%



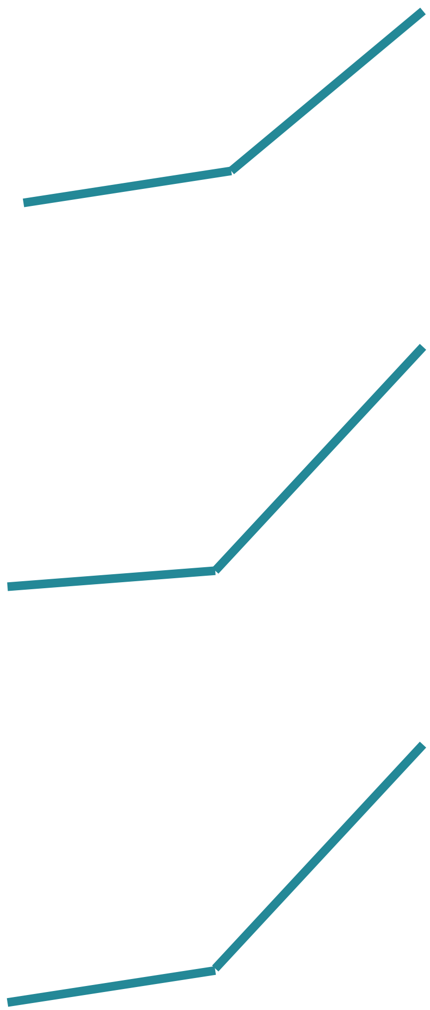
Extinction risk with 2040s climate

Change in population-specific extinction risk
from historical baseline across a wide range of ocean scenarios

Results: Extinction risk



Is there a tipping point for ocean conditions?



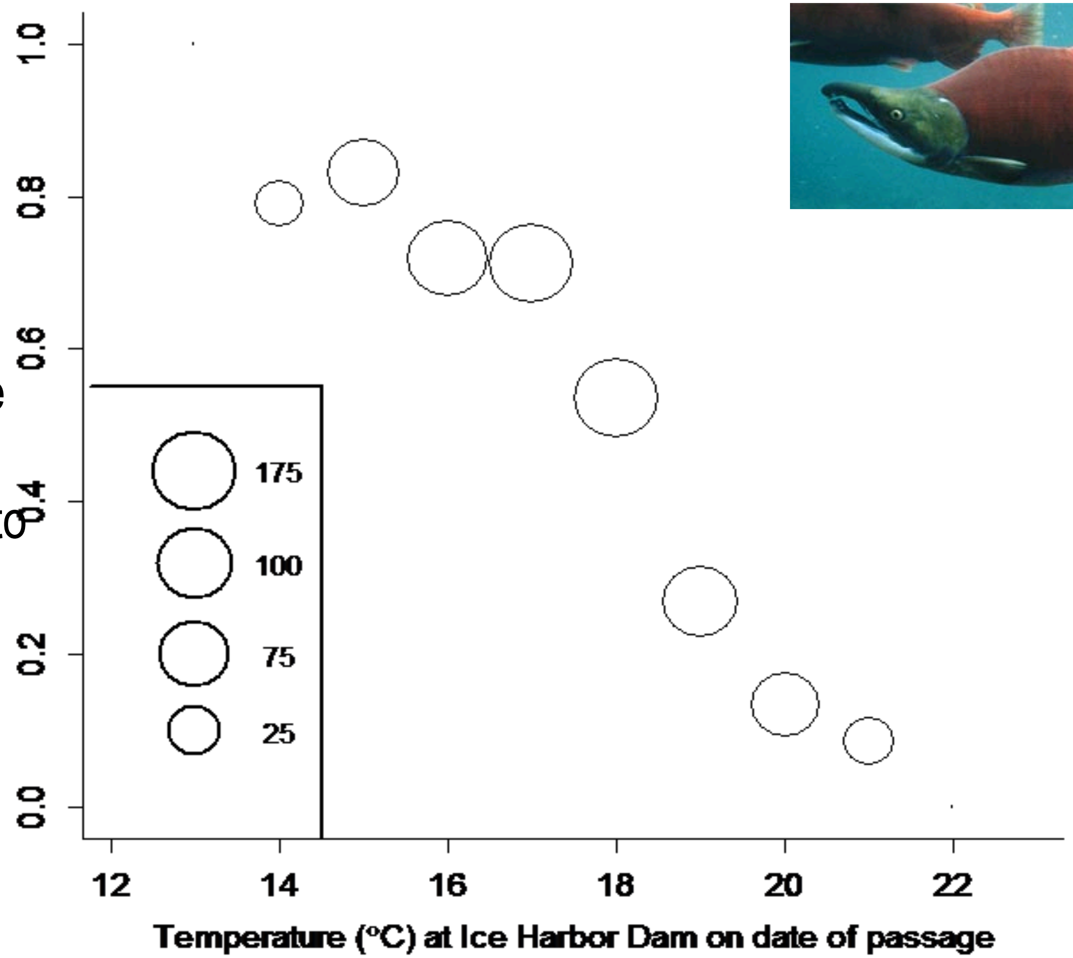
Threatened species recovery:

At the ESU / Columbia Basin scale, mainstem Columbia River and ocean conditions are crucial

Threatened species recovery:

For local decisions,
e.g. specific restoration actions,
individual population-limiting factors and
individual GCMs are most important

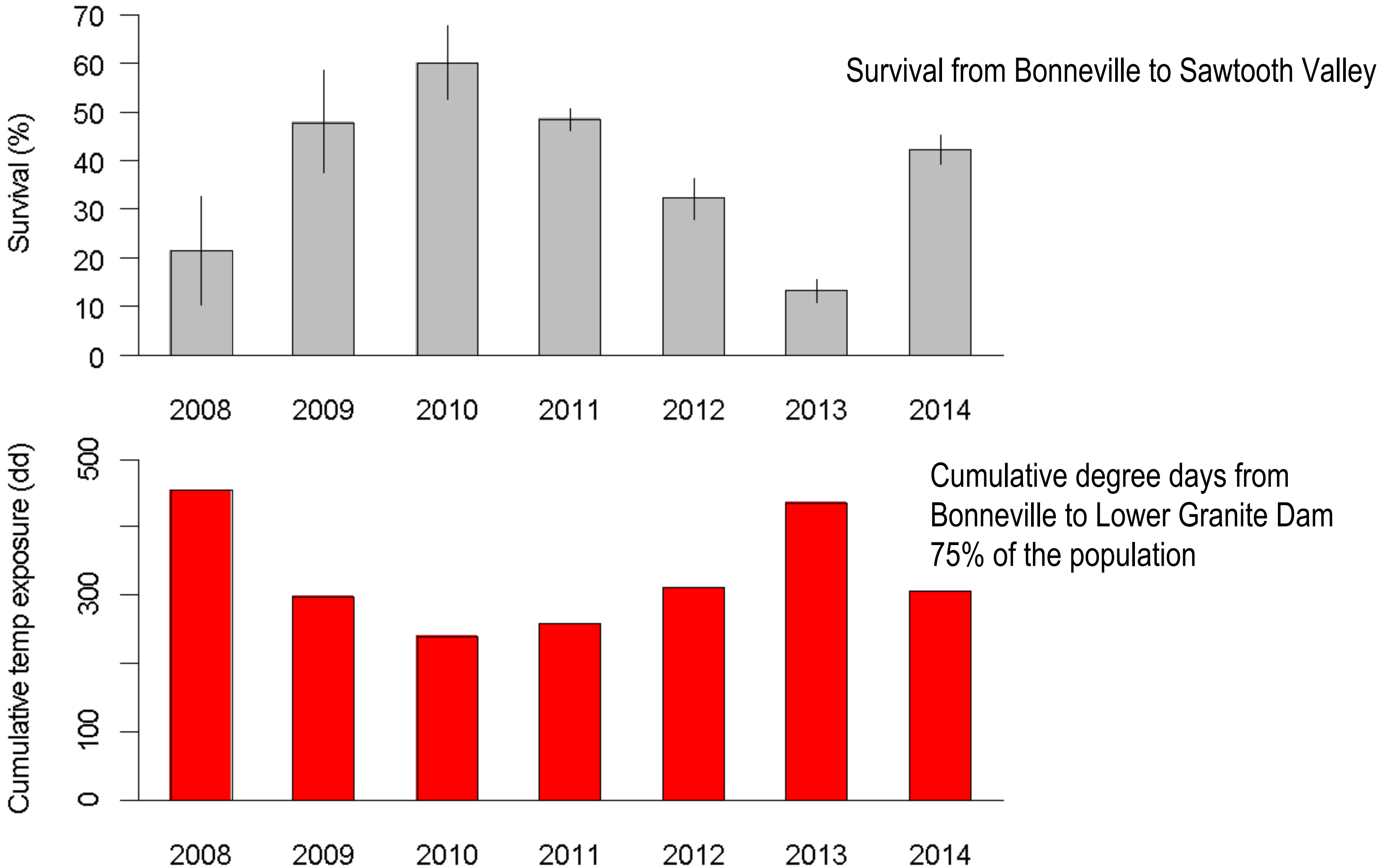
Upstream survival ~ temperature



Endangered Redfish Lake sockeye salmon survival from Lower Granite Dam to spawning areas

Crozier, L. G., B. J. Burke, B. Sandford, G. Axel, and B. L. Sanderson 2014. Adult Snake River sockeye salmon passage and survival within and upstream of the Federal Columbia River Power System. Research report to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Upstream survival highly variable



Upstream survival ~ temperature

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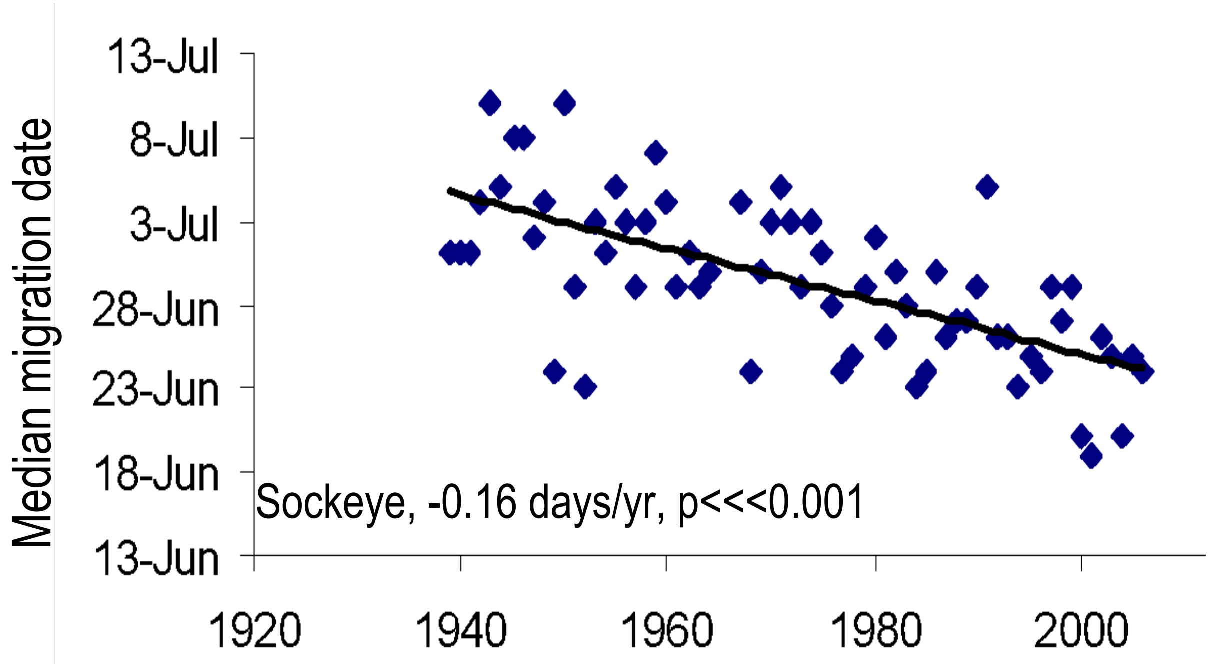
Crozier, L. G., B. J. Burke, B. Sandford, G. Axel, and B. L. Sanderson 2014. Adult Snake River sockeye salmon passage and survival within and upstream of the Federal Columbia River Power System. Research report to the U.S. Army Corps of Engineers, Walla Walla, Washington.

Columbia River sockeye are migrating earlier



Fish response:
Evolutionary and plastic changes in timing

Shift in reaction norm

1950s

1990s

Migration date

Crozier, Scheuerell and Zabel (2011) Am. Naturalist

Conclusions

- Climate change will greatly affect salmon even in the most pristine, high elevation habitat, with **different effects on different populations**
- Effects **accumulate over life cycle**
- Lowered survival might drive **evolutionary or plastic responses**; constraints are not well understood, and might limit future evolution
- **Uncertainty** in climate future more important in ocean than freshwater for most populations
- Management options:
  - Reduce other threats and impacts
  - Build resilience (abundance, habitat networks, diversity and refugia)
  - Triggers for additional actions

Questions?

THANK YOU

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